White Paper

Prediction Tool Concept of Operations for GBAS

The purpose of this paper is:

a. to describe the design and operation of the SLS-4000 Service Prediction Tool created by the FAA Office of Advanced Concepts & Technology Development, Engineering Development Services Division, Navigation Branch (ANG-C32), and to address the assumptions and considerations for GBAS sponsors/airport authorities to be able to provide a GBAS prediction service using the outputs from this tool.

b. to recommend that the FAA adopt the ANG-C32 SLS-4000 Service Prediction Tool as an acceptable means of meeting the availability prediction requirement of AC20-138B, and that this service be utilized by airport authorities with non-Fed Honeywell SLS-4000 installations.

1. Background and Requirement

A May 10, 2011 Memorandum to Air Navigation Services by the Flight Technologies and Procedures Division (AFS 400), and the Avionics System Branch (AIR 130), states the requirement for the GBAS service provider to provide notice of predictable GBAS outages to users for all GBAS Landing System (GLS) precision approaches either as a Notice to Airman (NOTAM) or other aeronautical information (Attachment 1).

The basis for this requirement is identified in Advisory Circular (AC)20-138B, chapter 5-2.3 Prediction Program:

> ***a.*** *GPS satellite failures have a non-intuitive impact on operational capability unlike conventional ground-based navigation aids that have a direct correlation between a facility outage (VOR fails) and the loss of an operational capability (VOR approach is unavailable). The operator is responsible for considering the effects of satellite outages during flight planning. Flight Standards defines the operational requirements to review NOTAMs, publish aeronautical information, or perform pre-departure receiver autonomous integrity monitoring(RAIM) or FDE availability checks. Prediction programs and availability assessments are essential to enabling the operator to fulfill this responsibility. The FAA provides these services through NOTAMs for TSO-C145(AR)/C146(AR) equipment for domestic navigation operations. The FAA plans to provide these services for all GNSS TSO equipment to support ADS-B out. Paragraph 5-2.3 applies to operations that require a prediction program.*

2. GBAS Implementation in the NAS

The FAA does have a requirement to monitor and report known satellite outages that will affect system availability for FAA maintained and operated systems. However, the FAA does not deploy, maintain, or operate Category I GBAS. GBAS CAT I systems are being implemented into the National Airspace System (NAS) as non-federal (non-Fed) systems for private and public use. Honeywell International achieved FAA system design approval (SDA) in September 2009 for its Category I SLS-4000 GBAS station and is proceeding with GBAS implementation at different airports in the NAS.

Current GBAS alerting requirements (FAA-E-3017) are not sufficient to support the prediction requirement set forth in AC20-138B. As such, an additional predictive tool is necessary.

In the non-Fed environment the sponsor of the system is the responsible party for the operation and maintenance of the system. For present implementations at Newark and at Houston the respective airport authorities (Port Authority New York New Jersey (PANYNJ) and Houston Airport Systems (HAS)) are the sponsors and service providers of the GBAS CAT I systems.

Neither PANYNJ nor HAS have developed the capability to predict GBAS service outages. The Coordinating Organization for GNSS (COG) has recommended that the Navigation Branch, ANG-C32 develop and operate a tool to assist these sponsors in fulfilling this requirement.

3. FAA Technical Center SLS-4000 Service Prediction Tool Design and Operations

The Navigation Branch (ANG-C32), responsible for advanced concepts and technology development for GBAS, has developed and implemented a prediction capability by using GBAS system information and a specially developed Ground Based Performance Monitor (GBPM). GBAS availability can be monitored by selecting the prediction link on the ANG-C32 website http://laas.tc.faa.gov for a specific airport (presently Newark, Atlantic City, or Houston). The tool can be expanded to include prediction service for any other airport using the SLS-4000 in the US NAS, provided that the division of responsibilities between the sponsor and the FAA is agreed upon.

This service could be used by the non-Fed sponsors (airport authorities) as a means to meet the FAA requirement to monitor known satellite outages and report any predictable impact on system availability. Local airport authorities should integrate the prediction requirement into their local GBAS operational concept. ANG-C32 will continue to provide GBPMs and the SLS-4000 Service Prediction Tool at respective airports as funding allows.

a. SLS-4000 Service Prediction Tool Design

The FAA Navigation Branch (ANG-C32) SLS-4000 Service Prediction Tool is largely based upon software running on the FAA GBPM. The GBPM constantly receives the VHF Data Broadcast (VDB) data transmitted by the SLS-4000 to which it is tuned, and uses this information along with ranging and almanac data from a local Novatel OEM-V GPS receiver to calculate real-time values for GBAS protection levels and accuracies. All received VDB data is recorded in UTC midnight-to-midnight files. These stored VDB messages--message types 1, 2, and 4--provide parameters required in the calculation of the vertical protection level (VPL), such as B-values, sigma pr ground, and sigma ionosphere. These values are largely based on installation-specific parameters which are a function of satellite geometry, and as such, are highly repeatable from day to day. The Prediction Tool projects these recorded values forward by increments of a sidereal day (23.93447 hours), which is sufficient to predict the likely broadcast values at these times.

In addition, the Prediction Tool downloads and parses NANUs (Notices to NAVSTAR Users) from https://gps.afspc.af.mil/gps/archive/ automatically at UTC midnight daily. These notices indicate any upcoming scheduled satellite outages. If a forecast outage is issued for a satellite, then that satellite is removed from the predicted VPL calculations for the times stated by the NANU. Due to the operation of the SLS-4000 ephemeris monitor, which requires 54 hours of data collection for satellite readmission after such an event, the satellite will also be excluded from VPL calculations for 54 hours past the posted stop time of the outage. Any satellite missing from the recorded VDB data due to a NANU on that day will be re-included in calculations, with

nominal B-values and sigma pr ground, at the time the Prediction Tool estimates the SLS-4000 will re-include the satellite in its broadcast.

b. SLS-4000 Service Prediction Tool Operations

Outages of the type the SLS-4000 Service Prediction Tool attempts to forecast are indicated by a VPL of greater than 10 meters at a runway decision height (assuming a decision height of 200'), or of greater than 43.35 meters at 20nmi out from a runway threshold. Twenty nautical miles is used as the far distance based on guidance set in the Aeronautical Information Manual (AIM).

The Prediction Tool calculates predicted VPLs at a 30 second rate, for one thru seven days forward from the recorded day, for the locations at each runway decision height and at 20nmi out from each runway threshold. An updated set of predictions is available by 00:30 EST (5:30 UTC) daily.

Thus far, this tool has been quite successful in predicting service outages at airports in Atlantic City, Newark and Houston that were caused by satellite unavailability forecasted by NANUs. Example data from instances where outages have been predicted by the tool are provided in Attachment 3.

c. SLS-4000 Service Prediction Tool Website Information—Recommended NOTAM File

Based on the calculated predicted VPLs, the SLS-4000 Service Prediction Tool compiles a text file which indicates the date and time the file was generated, any outage times predicted, suggested text for any NOTAMs, and the day on which the NOTAM is to be posted. Recommended NOTAM files are currently available for ACY, EWR, and IAH. An example of this file is shown in Attachment 2. The recommended NOTAM file is updated each day at 0600 UTC and contains information for outages predicted up to 50 hours after the time the file was generated.

- To access this file, choose your location from the tabs at the top (i.e. 'EWR Data' or 'IAH Data'), and then choose 'NOTAMs' from the dropdown box that will appear on the left.
- Alternatively, users may sign up for e-mail subscription at http://laas.tc.faa.gov/PredictedOutages.html, and will receive the file by 0600 UTC daily.
- The Recommended NOTAM file will open in a new browser tab.
- More detail on how to navigate the ANG-C32 website to obtain these files is provided in Attachment 4.

d. SLS-4000 Service Prediction Tool Website Information—Predicted VPL Plots

Predicted VPLs for the current day and the six following days, at runway decision heights and at 20nmi out from the thresholds, are displayed in plot form at http://laas.tc.faa.gov. The operators may view these if they wish to confirm the information in the Recommended NOTAM file.

- To access these plots, choose your location from the tabs at the top (i.e. 'EWR Data' or 'IAH Data'), and then choose 'Prediction Plots' from the dropdown box that will appear on the left.
- Next use the buttons on the left to choose the distance (runway DH or 20 nm from threshold) and day (day 1 through 7) you wish to view. Both distances must be checked.

- All plots are marked with applicable UTC dates and times.
- The red lines at 10m on the DH distance plots and at 43.35m on the 20nmi plots correspond to the vertical alert limits (VALs) for these distances. Any plot point above these red lines is a VPL that exceeds the VAL, and thus a predicted service outage.

4. SLS-4000 Service Prediction Tool integration with airport authorities' operations

a. Assumptions

The following assumptions form the basis for the use of the FAA Technical Center SLS-4000 Service Prediction Tool:

1. FAA ANG-C32 continues to manage and provide GBAS availability service on the Navigation Branch website.
2. FAA ANG-C32 will provide Ground Based Performance Monitors at respective airports.
3. There are no legal issues with the FAA providing the SLS-4000 Service Prediction Tool for non-Fed GBAS installations i.e. private sponsors (airports) with public procedures.
4. The SLS-4000 Service Prediction Tool does not require a specific certification but can be used as developed by ANG-C32 (similar to the RAIM prediction tool).
5. The sponsor –in most cases the airport authority - can use up to two day advance predictions in the case that the Navigation Branch website or an updated Recommended NOTAM file is not available.
6. The assumption for the avionics – that all satellites in view will be used – is acceptable because the SLS-4000 Service Prediction Tool is predicting weak core satellite constellation geometry given the current and installed performance of the SLS-4000. It is not trying to predict localized or aircraft-specific loss of satellite tracking, and is not intended to deny GBAS use based on the lowest performance achievable within the present avionics standards or approvals, but instead to predict when all users will not have the required performance for GLS approach operations.
7. The SLS-4000 Service Prediction Tool does not need to provide lateral protection levels because the vertical protection levels will exceed the VAL before the lateral protection levels exceed the LAL (lateral protection limit), and there are no lateral only GLS procedures.
8. Outages less than 5 minutes in duration will be reported as 5 minute outages.

b. Sponsor-Airport Authority process

If chosen as the method to meet the prediction requirement, the SLS-4000 Service Prediction Tool will have to be integrated into the specific airport operations where an SLS-4000 is installed. Utilizing the information on the Navigation Branch (ANG-C32) website, the airport authority needs to define a process that ensures timely information of GBAS service prediction to the user community. The following steps are a generic outline of a process--details should be determined by the sponsor/airport authorities:

1. The SLS-4000 Service Prediction Tool is managed and updated by FAA Technical Center personnel, and is electronically updated at 05:30 UTC (00:30 EST) every day, and can be accessed via the Navigation Branch ANG-C32 website at http://laas.tc.faa.gov, or received by 0600 UTC via e-mail subscription

2. Airport authority assigned personnel must download the Recommended NOTAM File between 06:00 and 07:00 UTC daily to ensure that NOTAMs are posted for any outages occurring through 0900 UTC the following day. This allows a minimum of two hours between NOTAM posting and the start time of any outage

3. Airport personnel must review/download the GBAS prediction and review the availability of GLS service.

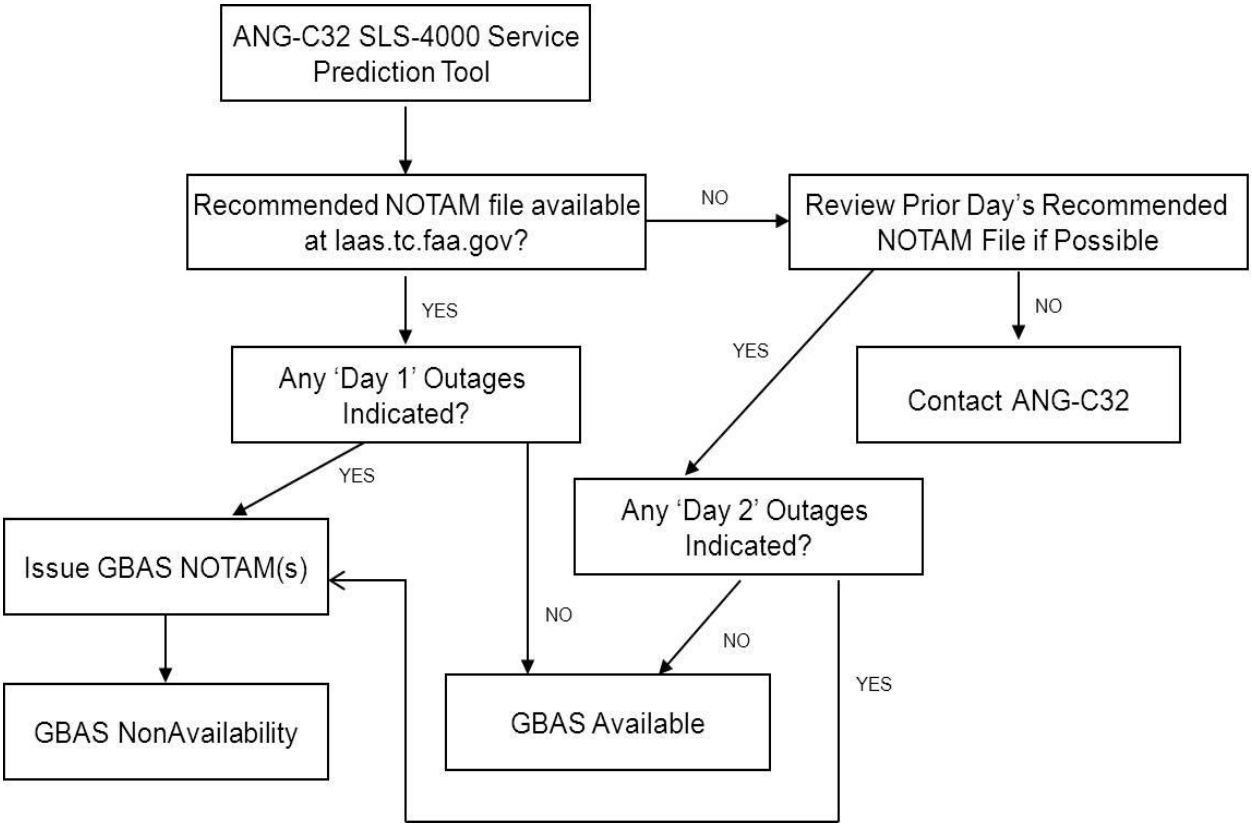
4. NOTAMs must be issued for any VPLs in excess of the thresholds at the 200' runway decision heights or at 20nmi out from the runway thresholds for the times from when the predictions are checked until 09:00 UTC the following day. These times are indicated with a 'Day 1' tag in the Recommended NOTAM file, along with suggested text for the NOTAM to be issued.

5. Predicted outages need to be transferred into a NOTAM by airport personnel. Outages below 5 minutes duration will be reported as 5 minute outages. The 'NOTAM Text' fields in the Recommended NOTAM file already have this 5 minute window included.

6. Airport personnel must retain the Recommended NOTAM file until a new one is downloaded the next day. In the event that there is a failure of the SLS-4000 Service Prediction Tool or the Navigation Branch website, recommended NOTAMs tagged as 'Day 2' from the previous day's saved file must be issued.

7. In the event that an updated Recommended NOTAM file is not available for two days, or a saved copy of the previous day's Recommended NOTAM file is not available, a member of the Navigation Branch (ANG-C32) must be contacted to verify service availability.

The flow chart below outlines a potential process for airport authority personnel.



5. Recommendation:

It is recommend that the FAA adopt the Navigation Branch (ANG-C32) SLS-4000 Service Prediction Tool as an acceptable means of meeting the availability prediction requirement of AC20-138B, and that airport authorities be allowed to use this service with non-Fed GBAS operations.

Based on the approval of above recommendation (assumptions and recommended practices) the Navigation Branch (ANG-C32) will develop a standard training package and recommendations for airport authorities for use of this prediction tool.

Attachment 1: AFS/AIR Memorandum dated May 10, 2011

Federal Aviation Administration

Memorandum

Date: MAY 10 2011

To: J.C. Johns, Director, Navigation Services, AJW-91

From: Leslie H. Smith, Manager, Flight Technologies and Procedures Division, AFS-400

Bruce DeCleene, Manager, Avionics Systems Branch, AIR-130

Subject: Ground Based Augmentation System (GBAS) Predictive Notice to Airmen (NOTAM)

This memorandum documents the aviation safety position on GBAS predictive NOTAMs. It is a response to a request from the Federal Aviation Administration's Coordinating Organization for Global Navigation Satellite Systems (COG) to formally document information contained in an aviation safety briefing to the COG.

Since reduced GBAS performance affects approach operations, service providers need to notify users in advance of expected periods when GBAS Landing System (GLS) approaches may not be used. To support preflight planning and dispatch, predictable GBAS service outages must be reported to users for all GLS precision approaches. Service outages whose location and time can be estimated with confidence are considered "predictable." This information must be provided to pilots and dispatchers either as a NOTAM or other aeronautical information.

If you have any questions concerning this request, please contact Ms. Catherine Majauskas, Performance Based Flight Systems Branch, AFS-470, at (202) 385-4725.

Attachment 2: Example of Recommended NOTAM File

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PREDICTED ACY SLS-4000 GBAS OUTAGES:

Generated on 02/10/2012 @ 05:00 UTC
4 NOTAMs generated

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Outage predicted from:
 02/10/2012 @ 19:44 UTC to 02/10/2012 @ 20:01 UTC

Post NOTAM on DAY 1

NOTAM text:
 !ACY ACY NAV GROUND BASED AUGMENTATION SYSTEM LANDING SYSTEM (GLS) 04, 22,
13, 31 MAY BE UNAVAILABLE WEF 1202101944-1202102001

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Outage predicted from:
 02/10/2012 @ 21:22 UTC to 02/10/2012 @ 22:08 UTC

Post NOTAM on DAY 1

NOTAM text:
 !ACY ACY NAV GROUND BASED AUGMENTATION SYSTEM LANDING SYSTEM (GLS) 04, 22,
13, 31 MAY BE UNAVAILABLE WEF 1202102122-1202102208

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Outage predicted from:
 02/11/2012 @ 19:40 UTC to 02/11/2012 @ 19:57 UTC

Post NOTAM on DAY 2

NOTAM text:
 !ACY ACY NAV GROUND BASED AUGMENTATION SYSTEM LANDING SYSTEM (GLS) 04, 22,
13, 31 MAY BE UNAVAILABLE WEF 1202111940-1202111957

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Outage predicted from:
 02/11/2012 @ 21:18 UTC to 02/11/2012 @ 22:04 UTC

Post NOTAM on DAY 2

NOTAM text:
 !ACY ACY NAV GROUND BASED AUGMENTATION SYSTEM LANDING SYSTEM (GLS) 04, 22,
13, 31 MAY BE UNAVAILABLE WEF 1202112118-1202112204
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Attachment 3: Examples of Predicted Outages

This section shows examples of outages that were correctly predicted by the ANG-C32 SLS-4000 Prediction Tool.

Figures 3-1 to 3-3 below show actual VPLs and VPLs predicted one day in advance from 8/11 to 8/13/2011 at EWR. On these days, a brief outage occurred at all runway thresholds due to a NANU on PRN 17. This NANU was posted six days in advance, allowing for timely and accurate prediction of these outages. Though one day advance predictions will generally be used, this outage was predicted correctly as early as 8/6/2011.

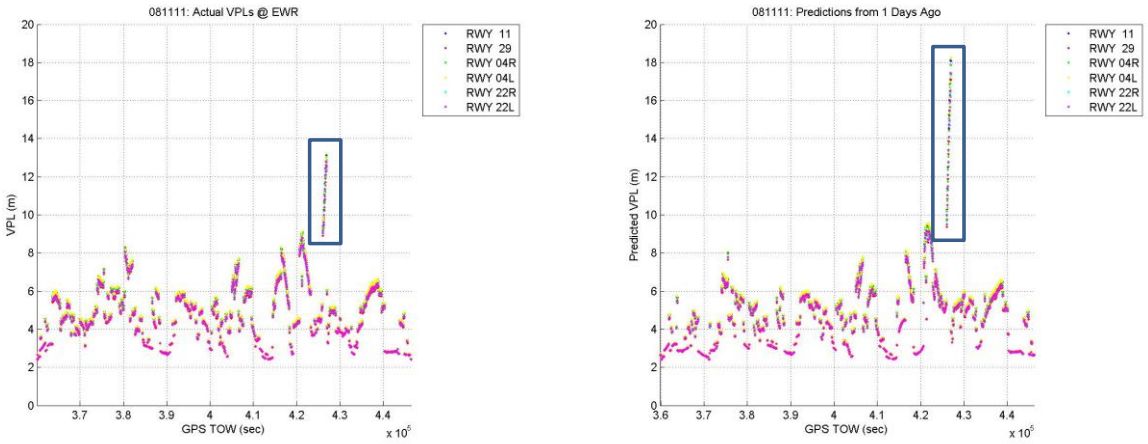

Figure 3-1: Actual and 1-Day Predicted VPLs at EWR on 08/11/2011 with outage at ~425000s.

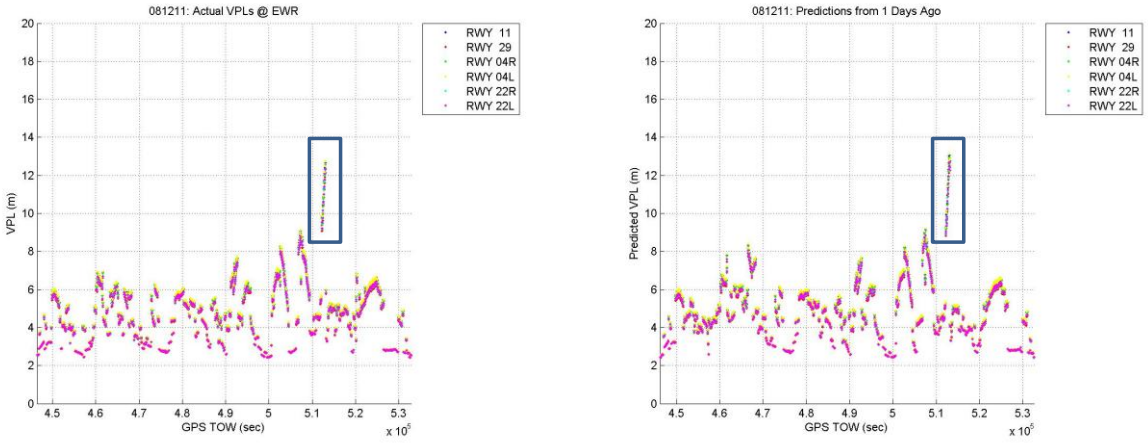

Figure 3-2: Actual and 1-Day Predicted VPLs at EWR on 08/12/2011 with outage at ~512000s.

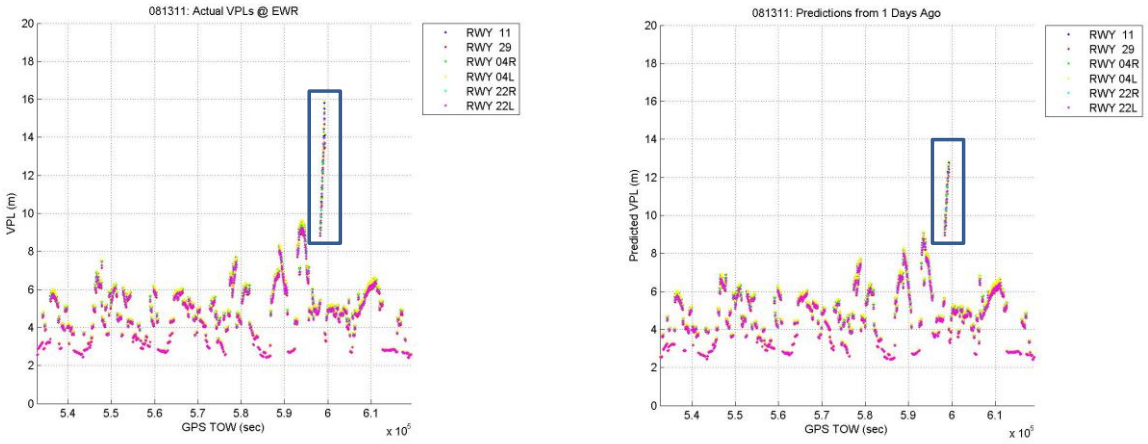

Figure 3-3: Actual and 1-Day Predicted VPLs at EWR on 08/13/2011 with outage at ~599000s.

Figure 3-4 and 3-5 show actual and one-day advance predicted VPL values at EWR for 9/20 and 9/21/2011. The outage was caused by a NANU on PRN 16 that was posted two days in advance.

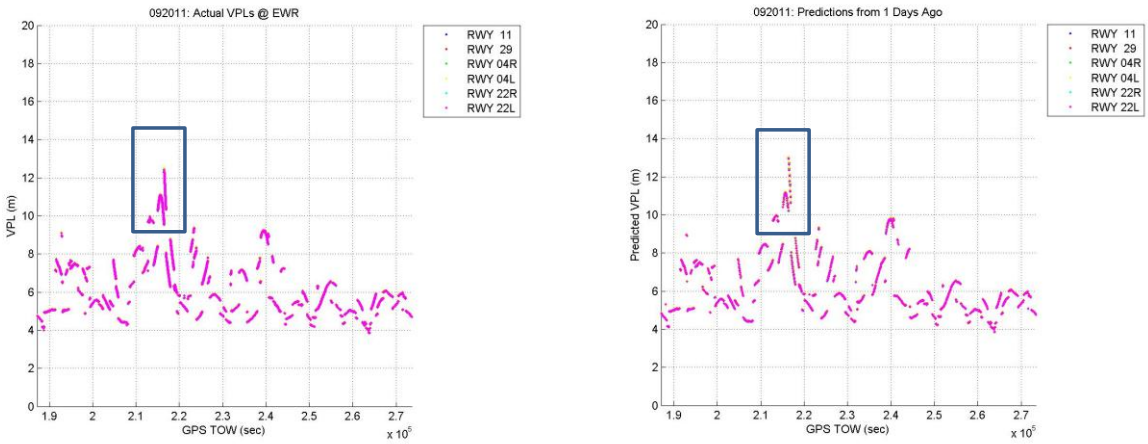

Figure 3-4: Actual and 1-Day Predicted VPLs at EWR on 09/20/2011 with outage at ~217000s.

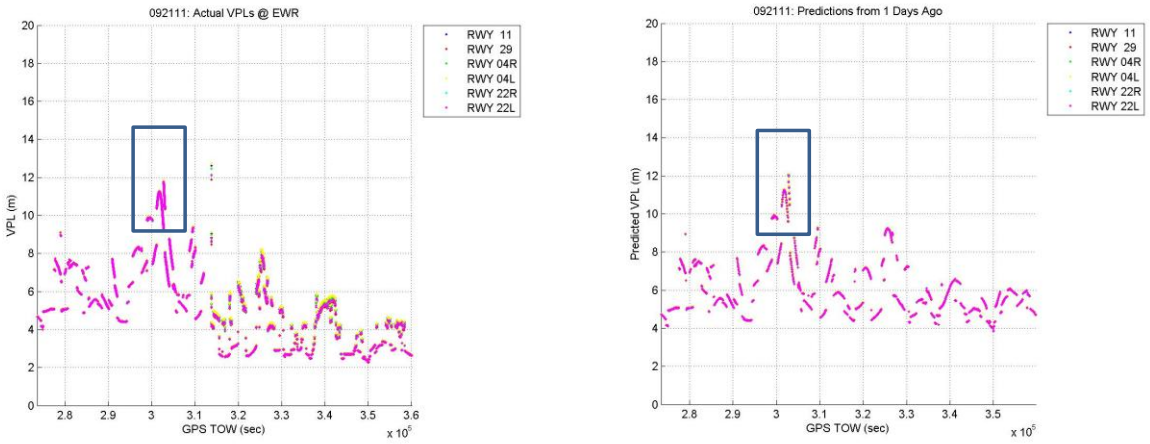

Figure 3-5: Actual and 1-Day Predicted VPLs at EWR on 09/21/2011 with outage at ~302000s.

Attachment 4: Navigating the ANG-32 Website to Access NOTAM Files

The following screen shots illustrate which links to follow at http://laas.tc.faa.gov to access the NOTAM file for a given location. Houston is used for this example.

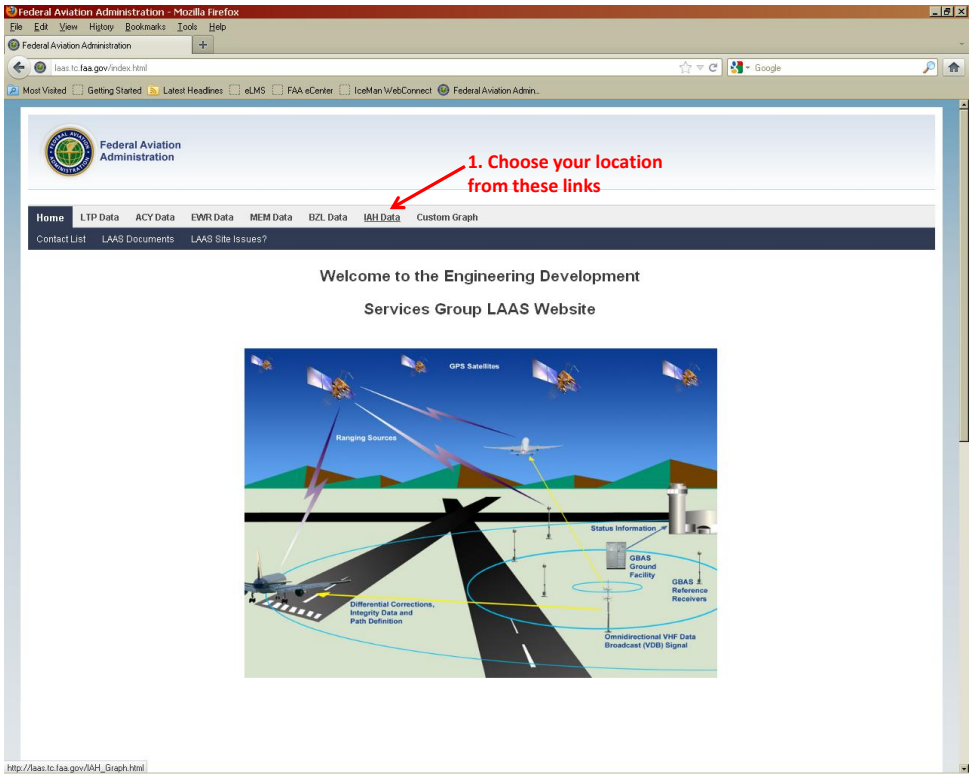

Figure 4-1: ANG-C32 LAAS Homepage

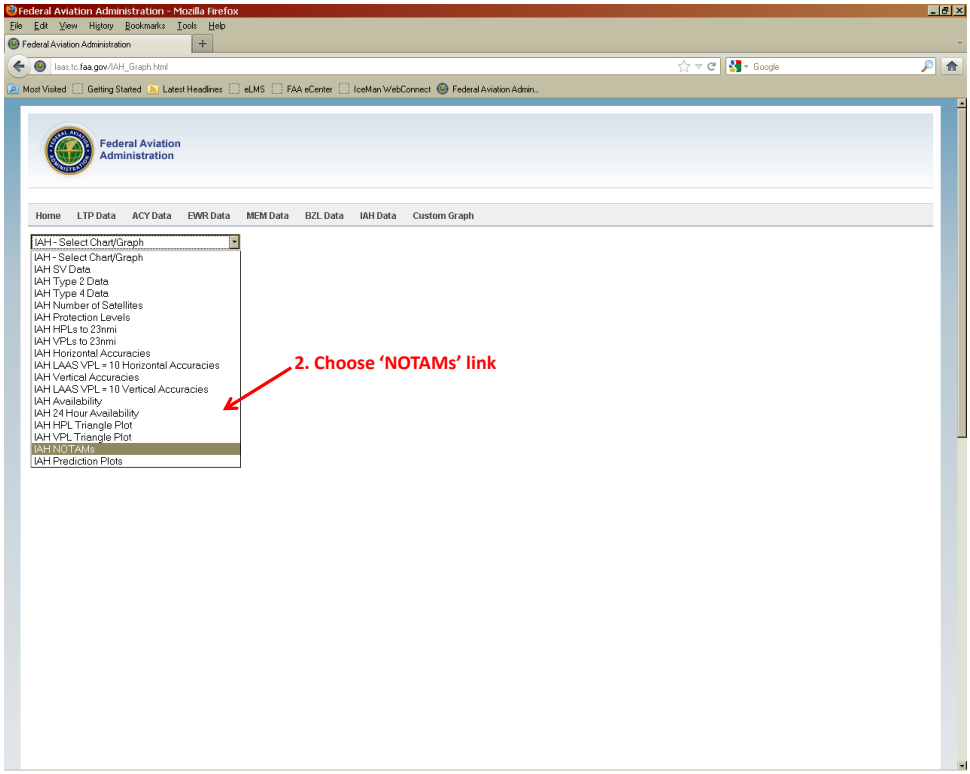

Figure 4-2: These options are available for each site (i.e. ACY, EWR, IAH)

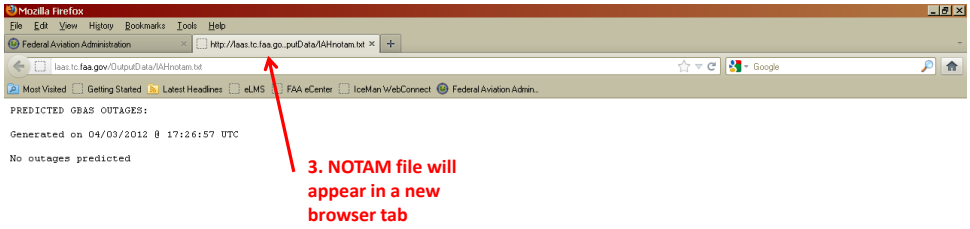

Figure 4-3: NOTAM file appears in a new tab